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Asphalt Underlayment Highway/Railway At-Grade Crossings: Designs, Applications, and Long-Term Performance Evaluations

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TECHNICAL SUMMARY

Title

Asphalt Underlayment Highway/Railway At-Grade Crossings:
Designs, Applications, and Long-Term Performances Evaluations

Introduction

Rehabilitation and/or renewal of highway/railway at-grade crossings frequently accounts for major track maintenance expenses for railroad companies and governmental agencies in the United States. The jointly used area represents a significantly expensive unit cost of the highway and railway line. Within this area, the crossing surface and trackbed replace the highway pavement structure.

An at-grade crossing is designed to fulfill its primary purpose of providing a clear and smooth path for the safe and comfortable passage of highway vehicles across railroad tracks and ideally will maintain a smooth surface and stable trackbed for a long period of time. At-grade crossings with long service lives greatly reduce the likelihood of costly and frequent disruptions that result from recurrent surface repairs.

Approach and Methodology

Historically, crossings have been expected to deteriorate at a faster rate and require reconstruction at more frequent intervals than the adjacent pavement and open-track. Structurally, railways and highways are typically designed very differently, but must co-exist within the common area of the crossing. When the roughness and deterioration of the crossing adversely affects the safety and reasonable traffic operations across the crossing, the crossing must be removed and replaced at high cost and inconvenience to the traveling public and railroad operations. If the crossing is replaced using similar materials and techniques, this can assure the occurrence of a similar series of events.

This report describes contractual arrangements, guidelines, standards, and design practices used by representative public transportation agencies and railroad companies to rehabilitate a grade crossing using asphalt underlayment technology. Detailed documentations of long-term performance evaluations of asphalt underlayment crossings are described and discussed for these selected state DOTs, public commuter/transit lines, and freight railroads involved with the development and adoption of this technology for various operating conditions throughout the

United States. Evaluations are conducted for crossings consisting of the eight most common types of crossing surfaces.

Findings

In recent years, numerous public transportation agencies and railroad companies have shown increased interest in adopting improved trackbed crossing designs to provide enhanced structural capability, thereby lengthening service lives and improving the performance of at-grade highway/railway crossings. Several public transportation agencies and railroad companies have developed and now specify guidelines and standards for the proper design and construction of highway/railway at-grade crossings that incorporate asphalt underlayments. Contractual arrangements and design practices used by ten representative public transportation agencies and railroad companies, described herein, attest to the successful application of this technology.

Long-term performances of hundreds of crossings incorporating asphalt underlayment indicate overwhelming justification for its use. No crossing deterioration as a function of trackbed pumping, settlement or premature deterioration of the crossing surface- indicative of inadequate trackbed support- has been detected for a wide variety of operating conditions. The only failure mechanism exhibited for a limited number of crossings is deterioration of the crossing material which can be readily replaced with minimum expense and interruption to highway and railway traffic.

Conclusions

Adding a layer of asphalt when constructing a new trackbed or renewing an existing trackbed will conceivably increase the cost of the crossing project compared to using an all-granular trackbed. However, for crossings that routinely exhibit short service lives due to unfavorable site conditions and poor performance, the additional cost for asphalt underlayment is minimal relative to the total cost of renewal. Typically, these crossings require the removal and replacement of the existing support and track materials with a premium surface applied. Often times, the added cost for the asphalt layer is less than 5 percent of the total renewal cost. If the crossing protection equipment is also replaced, the added percentage increase in cost will be even less. Though in most cases the cost of asphalt underlayment is minimal, it is important to note that the benefit-cost ratio varies from project to project. For crossings requiring frequent renewals, the added cost for the layer of asphalt will be more economically justifiable. Conversely, crossings that rarely exhibit structural deficiencies and maintain long service lives may not warrant the additional cost.

The time required to renew a crossing with a layer of asphalt varies considerably. This will largely depend on the project size and scope, as well as the pre-project planning and administration. There have been cases where two-lane highways have been completely re-opened to rail traffic within four hours and highway traffic within 8 to 12 hours. In other cases, crossing renewals that have involved additional appurtenant activities have required several days. The specifics of the train traffic and highway traffic at a given crossing will undoubtedly affect the planned crossing outage.

Recommendations

The findings and conclusions contained in this report are largely qualitative. The evaluations consider the longevity of acceptable performances for many types of crossings containing many different types of crossing surfaces. The scope spans many areas of the country and analyzes crossings on both heavy rail tonnage/high highway traffic freight lines and lower tonnage/high highway traffic commuter/transit lines. Although the conclusions appear somewhat repetitious for the ten agencies, the absence of available and proven quantitative evaluation measures makes it necessary to monitor a large and widely variable sample of crossings to accurately assess the performance of asphalt underlayment over long periods of time.

At present, there is not an established quantitative measure for gauging the performance of highway/railway at-grade crossings. A simple, direct measure of the relative rideability of crossings reflective of the crossings' smoothness/roughness and its adverse effect on vehicular driver/passenger comfort and safety is desired.

Publications

Rose, J.G. and B.R. Malloy. "Highway-Railway At-Grade Crossing Designs Containing Asphalt Underlayments". PROCEEDINGS of the 2017 Annual Conference of the American Railway Engineering and Maintenance-of-Way Association. September, 2017, 15 pages.

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SECTION 1 INTRODUCTION

Two very dissimilar modes of transportation jointly utilize highway/railway at-grade crossings. An adequately designed and maintained crossing provides a clear and smooth path for the safe and comfortable passage of highway vehicles across railroad tracks. The adequacy of the support structure within the crossing to accommodate the combined highway and railway loadings is a key aspect in assuring long service lives and desired performance levels for crossings. In recent years, numerous public transportation agencies and railroad companies have shown increased interest in adopting improved trackbed crossing designs to provide enhanced structural capability, thereby lengthening lives and improving performance measures of at-grade highway/railway crossings. An option during new construction or renewal of an existing crossing is to place a layer of asphalt pavement (termed "asphalt underlayment") below the ballast, similar to that used as highway paving material, to achieve an improved structural and waterproofing support layer. Numerous public transportation agencies and railroad companies now consider, based on an engineering evaluation of the particular site conditions, the use of asphalt underlayments when rehabilitating highway/railway at-grade crossings.

Rehabilitation and/or renewal of highway/railway at-grade crossings frequently accounts for major track maintenance expenses for the railroad companies and governmental agencies in the United States. The jointly used area represents a significantly expensive unit cost of the highway and railway line. Within this area, the crossing surface and trackbed replace the highway pavement structure.

An at-grade crossing is designed to fulfill its primary purpose of providing a clear and smooth path for the safe and comfortable passage of highway vehicles across railroad tracks and ideally will maintain a smooth surface and stable trackbed for a long period of time. At-grade crossings with long service lives greatly reduce the likelihood of costly and frequent disruptions that result from recurrent surface repairs.

Historically, crossings have been expected to deteriorate at a faster rate and require reconstruction at more frequent intervals than the adjacent pavement and open-track. Structurally, railways and highways are typically designed very differently, but must co-exist within the common area of the crossing. When the roughness and deterioration of the crossing adversely affects the safety and reasonable traffic operations across the crossing, the crossing must be removed and replaced at high cost and inconvenience to the traveling public and railroad operations. If the crossing is replaced using similar materials and techniques, this can assure the occurrence of a similar series of events.

SECTION 2 BACKGROUND

2.1 Typical All-Granular Trackbed Support

Historically, the most common track (sub-structural) support for highway/railway crossings is the typical trackbed consisting of unbound all-granular materials as depicted in Figure 2.1a. When the inherent lack of support for the highway vehicles in the track crossing area results in

excessive deflections of the crossing, the excessive deflections, combined with the lessening of the support strength due to the high moisture contents of the support materials, can ultimately result in permanent settlement of the crossing. This can adversely affect the vertical profiles of the highway and railroad in the immediate crossing area. An ideal trackbed design might include a high-quality substructure (or base) below the trackbed to provide similar load carrying, confining, and waterproofing qualities to the common crossing area – as typically exists in the abutting pavement sections.

2.2 Typical Asphalt Underlayment Trackbed Support

The use of a layer of hot mix asphalt within the track substructure – in lieu of, or in addition to, conventional all-granular subballast - is becoming widely utilized to provide ideal properties to the crossing (1,2). During the past thirty years, hundreds of crossings have been rehabilitated or initially constructed using this procedure. The basic process involves removing the old crossing surface and track panel followed by excavating the underlayment mixture of ballast, subballast, and subgrade to the required depth. These are replaced with compacted layers of granular subballast (optional), hot mix asphalt (termed "asphalt underlayment"), and ballast forming the structural support for the new track panel, and a new crossing surface, as depicted in Figures 2.1b and 2.1c.

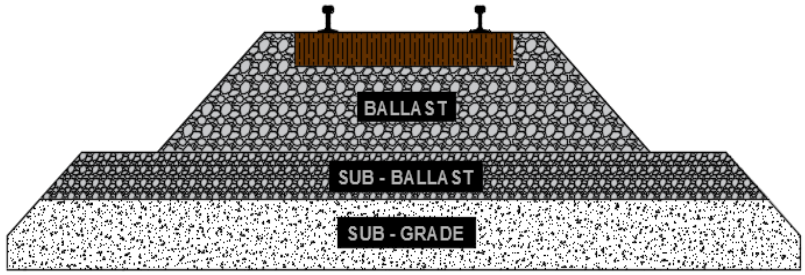
The addition of the layer of asphalt provides the ideal sub-structural support system for a highway/railway crossing; these being (3):

- Produces adequate strength to resist the combined highway and railway loadings thus minimizing stresses on the underlying subgrade,
- Minimizes vertical deflections and permanent deformations of the crossings due to highway and railway loadings so that the wear and deterioration of the crossing components will be minimized, and
- Serves to waterproof the underlying subgrade so that its load carrying capability will not be sacrificed even when placed on marginal quality subgrades.

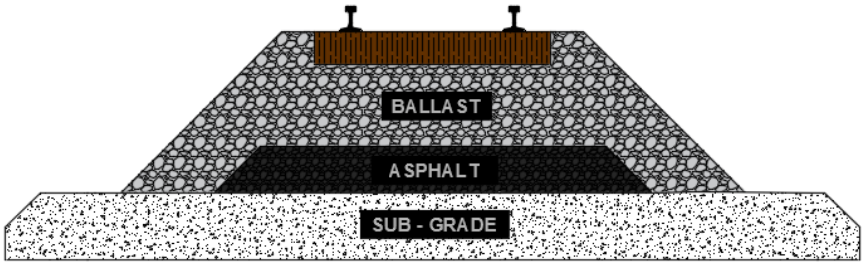
Numerous long-term tests and performance evaluations attesting to the superior performance of asphalt trackbed crossings have been conducted on heavy trafficked highway/railway crossings in Kentucky. The tests and corresponding results are described elsewhere (2,3,4,5).

2.3 Typical Asphalt Underlayment Trackbed Designs for Crossings

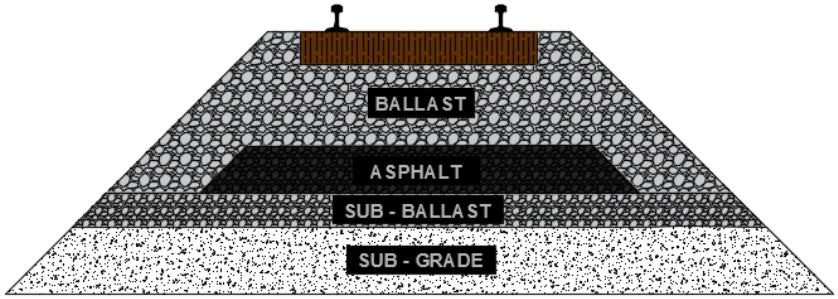
Typical dimensions for the asphalt underlayment layer are 12 ft (3.7 m) wide and 6 in. (150 mm) thick. For very poor trackbed support conditions and high impact areas, an 8 to 12 in. (200 to 300 mm) thickness of asphalt is commonly used. Thickness of the overlying ballast ranges from 8 to 12 in. (200 to 300 mm). Thickness of a granular subballast layer below the asphalt, if utilized, is usually 4 to 8 in. (100 to 200 mm) thick. The length of the asphalt layer will normally extend for a specified distance beyond the immediate crossing area. This distance is based on prevailing conditions at the specific site and the time available to perform the work. A distance of 10 to 20 ft (3 to 6 m) or more is desirable.



a) Typical All-Granular Trackbed



b) Asphalt Underlayment Trackbed



c) Asphalt Combination Trackbed

Figure 2.1. Typical All-Granular Trackbed (a) and Two Variations of Asphalt Trackbeds (b & c).

The asphalt mixture specification is normally the prevailing dense-graded highway base mix in the area having a maximum aggregate size of ¾ to 1½ in. (25 to 38 mm). The asphalt binder content can be increased by 0.5% above the optimum value for highway applications resulting in a low to medium modulus (plastic) mix, having design air voids of 1 to 3%. This mix is easier to densify to less than 5% in- place air voids and therefore facilitates adequate strength and an impermeable mat. Rutting of the plastic mix is not a concern in the trackbed since the pressures are applied through the ballast over a wide area. Bleeding and flushing are also of little concern since the wheels do not come in direct contact with the asphalt layer and the temperature extremes are minimized in the insulated trackbed environment (6,7,8,9,10,11).

SECTION 3 EXTENT OF UTILIZATION OF ASPHALT UNDERLAYMENT CROSSINGS

The use of asphalt underlayment has become increasingly significant in this country at select track sites and unique situations to provide increased structural support and waterproofing during maintenance and replacement of special trackworks - specifically for turnouts, crossovers, rail crossings, and wheel impact load detectors. Additional applications, similar in scope, include paving tunnel approaches and inverts and bridge approaches for various distances. A limited number of reasonably long sections of open-track, especially on capacity improvement projects, have had asphalt underlayment utilized at selected sites for specific reasons to justify the increased initial costs (12,13).

The large Class I railroad companies in the U.S. have been selectively using asphalt underlayment for new at-grade crossings and the rehabilitation of existing at-grade crossings based on engineering analyses of the benefits and logistics for the particular crossing site. Many regional and shortline railroad companies are involved as well. A select number of public agencies - including state public utility commissions, state DOTs, and urban commuter/transit lines - are participating with railroad companies in specifying and funding applications of this technology. Application is becoming a standard practice for selected railroads and public agencies for crossing renewals where the prevailing conditions have adversely affected the performance of conventional all-granular supported crossings. Several public agencies specify the use of asphalt trackbeds for all crossing renewals on which public funds are used (14,15,16,17,18).

Following are descriptions of contractual arrangements and design practices used by ten representative public transportation agencies and railroad companies that have taken proactive approaches to adopting this technology. The programs vary considerably among railroads and agencies; the following discussions are merely samples. Detailed documentations of long-term performance evaluations are described and discussed for these state public utility commissions, state DOTs, public commuter/transit lines, and freight railroads for widely varying operating conditions throughout the United States.

3.1 Portland & Western and WES/TriMet

The Portland & Western Railroad (P&W), a Genesee & Wyoming subsidiary, began using asphalt underlayment in 2006 during the renewal and upgrading of highway/railway crossings on its northwestern Oregon lines. Historically, maintaining serviceable highway/railway crossings presented challenges for this 520 mile (837 km) regional railroad. Frequent crossing renewals were common in this high annual rainfall climate on lines traversing less than desirable native subgrade soils. Muddy and settled crossings were common. However, since the adoption of asphalt underlayment and insuring that adequate drainage is incorporated with the impervious asphalt mat, the crossings have performed adequately with no mud pumping or track settlement. No extra track surfacing, crossing surface maintenance, or renewals have been required. For discussion, the P&W applications of asphalt underlayment are separated into three distinctly different categories of applications.

3.1.a Regular Street and Highway Crossings

During the past eleven years the P&W has renewed 4 to 6 typical highway/railway crossings per year using asphalt underlayment. The total number in service is around fifty with additional installations planned for 2017 and succeeding years. A portion of these were partially funded by the Oregon Department of Transportation, particularly on high-volume highway traffic crossings in urban areas. The typical track support section is composed of 6 in. (150 mm) of granular subballast, 6 in. (150 mm) of asphalt underlayment, and 12 in. (300 mm) of ballast.

3.1.b Long-Distance Street-Running Continuous Crossings

Of particular significance to the P&W is the predominance of long-distance middle-of-the-street running trackage in several cities. This was common to the predecessor Oregon Electric Line that operated frequent interurban passenger trains in the Portland suburbs. Crossings ranging from 2000 to 3500 ft (600 to 1100 m) long are common. These have typically required frequent and costly track maintenance activities to maintain smooth surfaces for both train and highway vehicle passage. This has included frequent surface replacements, roadbed injection, pavement milling, etc. Providing adequate drainage throughout these long distances to minimize settlement and deterioration and provide adequate trackbed support for the jointly used crossings has been difficult to achieve using conventional all-granular support structures.

Renewing the crossing surfaces and support structures for the poorly performing middle-of-street crossings began in 2009 in Independence with a 2000 ft (600 m) long Main Street crossing installed over four years using asphalt/rubber seal surfaces with concrete at selected cross streets.. This was followed with a 3,500 ft (1,100 m) long Holly Street concrete crossing in Junction City, depicted in Figure 3.1, also installed over four years. The P&W trackage has 2.9 miles (4.7 km) of middle-of-street-running crossings, scattered over six cities.

Performance of the two crossings to date has been very satisfactory. During 2017 P&W plans similar projects in two cites – 2,800 ft (850 m) long Front Street in Salem and 1,400 ft (425 m) long 4th Street in Harrisburg. These will be multi-year projects following the specifications and procedures used for the initial two long-distance street crossings.

3.1.c WES/TriMet Commuter Line

A short section of the P&W trackage is also utilized by the Westside Express Service (WES) Commuter Line, an extension of the extensive TriMet rail passenger system in the Portland area. Sixteen commuter trains operate weekdays in each direction during peak AM and PM periods. The line serves freight trains during the mid-portion of weekdays, nights and weekends.

The line was extensively upgraded in 2007/2008 for the initiation of commuter traffic and improved and increased freight traffic operations. Various improvements were made to the track, including installing new/larger rail and concrete ties. Twelve of the 17 public street crossings on the line were deemed in need of renewal and subsequently fitted with asphalt underlayment during the upgrade. An additional WES crossing was renewed with asphalt underlayment in 2010. This crossing at Durham Avenue is shown in Figure 3.1.

Figure 3.1. The 3,500 ft (1,100 m) long Holly Street Middle-Of-Street Crossing in Junction City (left) Containing Asphalt Underlayment. Durham Avenue (right), one of 13 Crossings on the WES Line Containing Asphalt Underlayment.

The in-service WES crossings are performing adequately with no settlement or deterioration. Wood ties and Pandrol clips were used in the immediate crossing areas rather than concrete ties. Asphalt underlayment is planned when the remaining four at-grade crossings require replacement and renewal.

3.2 West Virginia Department of Transportation

The WVDOT began utilizing asphalt underlayments during the rehabilitation of crossings in 2000. Its use soon accelerated. For several years, when WVDOT funds are used for crossing rehabilitation projects on state highways, the use of asphalt underlayment has been considered a standard practice. Since 2000, an average of seven to eight crossings has been underlain with asphalt per year. It is estimated that over 145 crossings have asphalt underlayment, the oldest having been in service for 16 years. Most of these renewals have been on heavy tonnage, high traffic crossings and a large percentage have routinely exhibited deterioration soon after renewing using standard granular trackbed support materials.

Normal practice is to use a high-type surface material, commonly concrete precast panels, and improved support and drainage, achieved with a 6 in. (150 mm) thick asphalt underlayment. The asphalt layer is normally placed 12 ft (3.6 m) wide and extends 10 to 20 ft (3.0 to 6.1 m) beyond the crossing surface based on an engineering evaluation of the site. This practice qualifies as a betterment program to upgrade crossings for improved performance and increased service life. This is considered a benefit to the traveling public. WVDOT funds the crossing surface material differential (premium material vs. railroad standard material), asphalt underlayment, traffic control, drainage pipe (if needed), and tie differential for longer ties. The railroad company contributes the costs of labor and equipment.

Since the program began, no crossings have failed due to lack of substructure support or excessive settlement; all have remained smooth and serviceable. A nominal number have required surface replacement after ten or so years due solely to the deterioration of the surface materials particularly on heavy traffic crossings.

WVDOT standards dictate that the minimum crossing service life (assumes the crossing remains reasonably smooth) should be a minimum of ten years. This long life expectancy also enables the railroad company to "skip" crossings at least once for 5-year maintenance planning, only needing to routinely adjust the geometry of the open track. Numerous crossings with asphalt underlayment have exceeded the useful life expectancy of ten years, a tremendous benefit to the traveling public since the crossings are seldom closed for renewal. Previously the service lives for many of these crossings, particularly in the heavy coal-haul routes, were as short as two years. Figure 3.2 contains recent views of two WVDOT long-life crossings that have not had any maintenance since they were installed, although the pavement approaches are showing some deterioration.

Figure 3.2. WV Route 2 at Ashton (left) Placed in 2001 and 5th Avenue W (US 60) in Huntington (right), Placed in 2000. These are Exemplary of WVDOT Asphalt Underlayment Crossings Exceeding the Minimum Service Life of Ten Years. The Only Detrition is Slight Raveling of the Asphalt Approaches.

3.3 Caltrain

This 55 mile (88 km) long regional rail link along the San Francisco Peninsula began using asphalt underlayment in 1999 for the rehabilitation/renewal of at-grade street crossings, pedestrian crossings, and station platforms. During the intervening 18 years, 21 multi-track street crossings, involving 43 track underlayments, and 8 station platforms, involving 19 track underlayments throughout the lengths, have been rehabilitated/renewed using this technology. This mixed traffic line carries caries frequent commuter trains, over 500 per week, and a limited number of UP local freight trains during the evening hours.

Construction details are contained in Caltrain's Standard Drawings and Practices. An engineering evaluation is performed to determine unique conditions at each site that might influence the specific design. After removing the old crossing surface and roadbed materials, considerable attention is given to preparing the roadbed for the trackbed. This involves drainage

considerations and thorough compaction of the existing or modified roadbed, ensuring a well-compacted 6 in. (150 mm) minimum thickness of compacted subgrade/roadbed.

The materials for the asphalt underlayment, ballast, and crossing surface must conform to the provisions of Caltrain's Standard Specifications. The underlayment mix is designated dense-graded Type A Mix with ¾ in. (19 mm) maximum size aggregate gradation. It is placed as a layer 8 in. (200 mm) thick, with either a machine or blade, and thoroughly compacted. The underlayment layer is placed 12 ft (3.7 m) wide and extends a minimum of 10 ft (3 m) along the track beyond the ends of the crossing surface. A layer of ballast, 9 in. (225 mm) thick, is placed above the asphalt. Precast concrete panels are considered standard crossing surfaces.

The crossings have all exhibited satisfactory performance since installation. No subgrade support issues have been observed and the crossings remain smooth and serviceable, some being in service for as long as 18 years. Based on demonstrated performance and engineering evaluations, the use of asphalt underlayment is considered the standard design for railway/highway at-grade crossings, pedestrian crossings, and station platforms on Caltrain's mainline.

3.4 Metrolink

This large commuter rail system in the Los Angeles area of Southern California presently consists of seven lines totaling 388 miles (624 km) in extent and continues to expand with additional lines. Metrolink began using asphalt underlayment in 2007 for at-grade railway/street crossings. Since that time, numerous crossings have been underlain with asphalt. It is considered standard practice for all newly constructed and rehabilitated crossings. The design is similar to that specified by Caltrain, except that only 6 in. (150 mm) thickness of asphalt underlayment is used. The designs are contained in Metrolink's Standard Book of Specifications.

The performances of the crossings have been satisfactory. Minimal settlement has been observed and the crossings have remained smooth and serviceable, requiring no maintenance. Recent views of typical streets on Caltrain and Metrolink underlain with asphalt are shown in Figure 3.4.

3.5 Illinois Commerce Commission and Department of Transportation

The Illinois General Assembly established the Grade Crossing Protection Fund (GCPF) in 1955. The program is administered by the Illinois Commerce Commission (ICC) and the funds are distributed by the Illinois Department of Transportation (IDOT). The ICC has primary administrative authority over approximately 7000 local roads and street public crossings and IDOT has primary authority over approximately 700 state roads and highway public crossings on the state road network.

Utilizing a portion of the GCPF for rehabilitation/renewal of highway-rail grade crossing surfaces began in 2009 with state fiscal year 2010 (July 1, 2009), as a component of the ICC

Figure 3.4. Caltrain's San Mateo 1st Street Crossing and Station Platform (left) Placed in 2,000 Using Hot-Mix Asphalt Mixture and Metrolink's Osborne Street Crossing (right) in the Sun Valley Area Placed in 2013 Using a Cold-Mix, Polymerized Emulsion Asphalt Mixture. These Crossings have Exhibited Excellent Performance, Typical of all Caltrain and Metrolink Street Crossings Underlain with Asphalt.

crossing safety improvement program. GCPF assistance is granted on a per-request basis. Railroads may only apply for assistance on surface renewal projects at grade crossings that are located on local roads and streets. A formal letter of request, following specific guidelines established by the ICC, must be submitted. The GCPF is used to reimburse railroads for all materials, including contract labor (asphalt paving, traffic control, etc.). The railroads cover all labor costs to install new crossing surfaces.

To qualify for assistance, selected grade crossings must meet several requirements set forth by the ICC; primarily the highways' annual average daily traffic (AADT) volumes and whether a crossing is along a designated truck route. The ICC specifies apportionment of the crossing surface rehabilitation component of the GCPF based on railroad class; Class I railroads receive 75%, Regional railroads receive 5%, and Short-line railroads receive 20% of the allocated funds.

The primary funding source for IDOT grade crossing surface renewal projects is the IDOT Central Office appropriations distributed to each district on a yearly basis. Federal Safety Funds (Section 130) can include a crossing surface, but only if an appropriate signal upgrade is also part of the project. Additional local and state funds may also be used. As is the case with projects funded by the GCPF, the Section 130 fund covers only the cost of materials. Additional costs, including labor and miscellaneous costs are absorbed by the railroad.

Beginning in FY2010 the railroads began to selectively seek reimbursement for installing asphalt underlayments. Asphalt underlayment is required for all crossing surface renewals administered by the ICC on designated truck routes regardless of AADT, and for all crossings on roads/streets with AADT > 5,000 vehicles per day. Since 2010, 32 crossing surfaces have been rehabilitated with asphalt underlayment on the ICC network of local roads and a similar number rehabilitated with asphalt underlayment on the IDOT highway network.

The asphalt layer is normally specified as 6 in. (150 mm) thick, 12 ft (3.6 m) wide, and extends a minimum of 25 ft. (7.6 m) beyond ends of the crossing. The crossings containing asphalt underlayment, located mainly on high volume highway and truck routes, have performed to ICC and IDOT expectations. Additional crossing surfaces are scheduled for utilization of asphalt underlayments in 2017 on the ICC and IDOT renewal programs; the on-going practice continues to expand in scope statewide.

3.6 Indiana Shortline Railroads

Two reasonably-sized shortline railroads, both with primary trackage in the state of Indiana, have been proactive in recent years with the use of asphalt underlayment for the rehabilitation, renewal, and upgrading of at-grade crossings. It has been necessary for both of these shortlines to upgrade the quality and class of the lines to accommodate increased rail traffic volumes. The Indiana Department of Transportation (INDOT), using state funds and contributions from local highway authorities, has funded a portion of the crossing projects. However, public funds are used only under the condition that significant upgrades to the highway and street aspects of the crossings are included in the project.

3.6.a Louisville & Indiana (L&I) Railroad

The L&I Railroad is a 106 mile (171 km) line providing a direct north-south route through the south-central portion of the state from Indianapolis to Louisville, KY. The line is currently being significantly upgraded to carry increased rail traffic in conjunction with CSX Transportation.

This railroad began installing asphalt underlayments in the late 1990s during the rehabilitation and upgrading of numerous at-grade crossings that had degraded due to deferred maintenance of the crossing surfaces and trackbed. By 2010 L&I had installed asphalt underlayments at 30 or more crossings, about two-thirds with partial funding from public funds. These crossings represent many of the heaviest highway traffic crossings on the line. Figure 4 depicts a typical crossing.

During the present programmed track upgrades, particularly the renewal of the rail with larger size new rail, many of the crossings - which had been renewed in recent years with new track panels and crossing surface and improved trackbed support with asphalt underlayments - did not require upgrades. The performances of these particular crossings were deemed adequate for several more years of service. The rail-exchange team merely “skipped” the crossings, thus providing minimal disruption to the traveling public and savings for the railroad company. One of these crossings is depicted in Figure 3.6a. Some of the shorter crossings in the rural areas were temporarily removed recently during the rail renewal and track upgrade.

The crossings containing asphalt underlayments have provided satisfactory performance all along the line, providing smooth, level crossings for normal operation of the railroad and acceptable comfort and safety for the motoring public.

Figure 3.6a. Charlestown-New Albany Road Crossing in Jeffersonville (left) Installed in 2003; State Route 256 Crossing in Austin (right) Installed in 2007, Recent Rail Upgrade is shown on Left Bottom, (Inset Bottom Right shows Sept. 2015 Weld), the 9-Year Old Existing Crossing was Unaffected.

3.6.b Indiana (INRD) Railroad

The INRD Railroad is a 250 mile (400 km) line providing an east-west route through the southwest portion of the state from Indianapolis to southern Illinois. The line has been significantly upgraded in recent years to carry increased coal volumes and intermodal traffic. This railroad began installing asphalt underlayments about eight years ago during the rehabilitation and upgrading of numerous at-grade crossings in anticipation of the increased rail traffic volumes. During the past eight years INRD has installed upwards of 25 or more crossings in the two states, several of these have involved partial funding from Indiana and Illinois public agencies. Most of the crossings upgraded with asphalt underlayment and premium crossing materials have been on high volume highway crossings and in urban areas.

Of particular significance is the enhanced quality of crossings in the city of Bloomington. Four high-volume highway crossings, three within close proximity to the University of Indiana, were renewed and upgraded with premium crossing surfaces and asphalt underlayments during 2011 and 2012.

The crossings containing asphalt underlayments have provided acceptable performances in both of the states of Indiana and Illinois. All crossings have remained smooth and serviceable assuring typical operations for the railroad and desired comfort and safety for the motoring public. INRD continues to selectively use asphalt underlayments during the rehabilitation and renewal of highway/railway crossings having concrete panel surfaces installed.

<u>3.7 Denver's RTD FasTracks – Eagle P3 Project</u>

FasTracks is Denver's RTD (Regional Transportation District) voter-approved transit expansion program – the largest in the nation – transforming transportation through the Denver metro area. This program, approved in 2004, augments the earlier completed light rail passenger lines serving the Denver Metro Area.

The Eagle P3 Project was approved in 2010. It includes the construction of three commuter lines as part of RTD's commuter rail line system. The project is being delivered and operated under a concession agreement that RTD entered into with a "Concessionaire" known as Denver Transit Partners (DTP); the team is composed of several large companies. The Eagle P3 Project concession agreement requires DTP to design, build, finance, operate, and maintain three lines – A line, G. line, and B line. The A & B lines opened in 2016; the G line is anticipated to open in 2017.

Of specific interest to this discussion was the decision by the DTP's design team to specify the use of asphalt underlayment designs for trackbed support within the at-grade railway-highway/street crossings for the three new lines. The fact that the long-term maintenance agreement that DTP must adhere to for the next thirty years dictated that premium designs, materials, and construction techniques should be used to minimize subsequent maintenance expenditures.

There are 52 at-grade highway/street crossings along the three routes, 10 of these crossings are located in flood plains requiring direct fixation crossing design containing ballastless tub concrete crossings positioned on lean concrete base. The remaining 42 crossings contain typical ballast and granular subballast including asphalt underlayments.

The specific asphalt underlayment trackbed design layers consist of 5 in. (125 mm) asphalt underlayment, placed 15 ft. (4.6 m) wide extending 10 ft. (3.0 m) beyond each end of the crossing. The asphalt layer is topped with 12 in. (300 mm) ballast for the typical ballasted track.

Maintenance requirements and serviceability measures will be closely monitored during succeeding years for these three lines to determine the effects of the specific designs on the costs and warranty implications of the executed contractual obligations of the concessionaire. One of these studies will evaluate whether the additional cost of installing asphalt underlayments under the highway/street crossings and turnouts will be recovered due to expected lowered maintenance costs and improved service metrics.

3.8 Iowa Department of Transportation

The Iowa Department of Transportation (IowaDOT) initially instituted an at-grade crossing management program in 1973 with the introduction of the Grade Crossing Surface Repair Fund (GCSRF). In 1999 all primary crossings were taken from the database and ranked by condition criteria and funded under the Primary Grade Crossing program using $1 million dollars from the Primary Road Fund.

A ranking system is used to determine priorities for funding crossing surface renewals using Primary Grade Crossing Funds. The system is based on prioritizing nineteen engineering factors unique to the specific crossing. Crossing life expectancy for crossings renewed with conventional all-granular support was often only two years for crossings that historically

exhibited structural problems and associated pumping/settlement. During the first two years of the Primary Program, 30 to 35 crossings were funded to address the degraded crossings quickly.

Figure 3.7. RTD Crossing Under Construction in 2013 (left) and Finished View in 2017 of Miller Street Double Track crossing on the G Line (right) with BNSF Line on Far Left.

Beginning in late 2000 the IowaDOT began using asphalt underlayment during the renewal of selected crossings, particularly those exhibiting short service lives. Since that time the backlog of eligible projects has significantly decreased and by 2010 the yearly renewals were reduced to less than five as the service lives of the crossings underlain with asphalt were extended significantly requiring less frequent renewals.

It is estimated that since 2000, 90 to 100 crossings on the IowaDOT primary system have been underlain with asphalt. It is considered standard practice when IowaDOT funds are utilized to renew/upgrade crossings.

On crossings where asphalt underlayment has been used, no crossing failures have occurred due to a lack of structural support or excessive settlement when specified IowaDOT practices are followed. The service lives for the asphalt underlayment crossings have increased significantly. A few precast concrete panels have cracked under particular impact loadings and required replacement, but no settlement issues were involved. Additionally, railroad production track maintenance work can normally skip the crossings for at least one or two maintenance cycles since only minor settlement is observed and only normal weathering of the exposed crossing materials is evident. Based on sixteen years of observing the improved performance and longer service lives of at-grade crossings underlain with asphalt, numerous benefits have been gained by public agencies and railroad companies:

3.9 Kentucky Transportation Cabinet

The Kentucky Transportation Cabinet (KYTC) began evaluating asphalt underlayment in combination with economical timber/asphalt crossing surfaces during the renewal of five L&N/SBD Railroad (later CSX) heavy traffic at-grade crossings in Central Kentucky during the early/mid 1980s. Before renewal, these crossings were frequently in deplorable conditions, exhibiting a combination of mud pumping, excessive settlement, and surface deterioration - all of which contributed to unacceptable rideability conditions and led to frequent maintenance and replacement. During the succeeding thirty years these crossings have performed very well, only

requiring renewal of the economical crossing surfaces at 12 to 15-year intervals as a result of deterioration of the surface materials due to long-term weathering and exposure. Figure 3.9 depicts the current condition of a CSX crossing renewed with asphalt underlayment in 1984.

The application of asphalt underlayments by KYTC during the renewal/rehabilitation of crossings began in earnest about 2000 and during the succeeding twelve years, 68 crossings were underlain with asphalt. The predominance of these crossings was initially in Eastern Kentucky on heavy-haul coal highways and CSX coal lines. Later crossings sites included NS and Paducah & Louisville and CSX lines throughout the state. The crossings that were selected had historically required frequent maintenance and renewal to maintain acceptable serviceability and ride quality. Figure 3.9 shows the condition of a CSX crossing in western Kentucky ten years after renewed with asphalt underlayment.

The long-term performances of the 73 at-grade crossings in Kentucky containing asphalt underlayments within the track substructure, for a variety of typical crossing surface materials, were documented in a Kentucky Transportation Center 2014 report (16). The findings from the study indicated that the performance of crossings rehabilitated/renewed with asphalt underlayment had been excellent, with no crossing failures due to excessive settlement, ballast fouling, or mud pumping. The services lives had been significantly improved, as the crossings had remained smooth and serviceable for longer periods than the preceding crossings that used conventional all-granular renewal techniques. A small percentage of the crossings had experienced deterioration of the crossing surface materials; this largely due to inherent aging of the surface materials.

Further evaluations indicated that economical crossing surfaces, such as rubber seal/asphalt and timber/asphalt, can be expected to perform as well as their more expensive premium counterparts provided the crossing support is adequately designed, the crossing is properly installed, and efficient drainage is achieved.

Figure 3.9. Pike Street Crossing (left) in Cynthiana, Renewed with Asphalt Underlayment in 1984, Surface Replaced Twice During the 32 Intervening Years. US 60 Crossing (right) at Stanley, Ten Years After Renewal With Asphalt Underlayment, Still in Perfect Condition in 2012.

KYTC's early experimentation and documented experiences with asphalt underlayment for at-grade crossing rehabilitation/renewals has served as a precursor for numerous other railroads, state DOTs, and governmental agencies.

SECTION 4 CONCLUDING REMARKS

In recent years, numerous public transportation agencies and railroad companies have shown increased interest in adopting improved trackbed crossing designs to provide enhanced structural capability, thereby lengthening service lives and improving the performance of at-grade highway/railway crossings. Several public transportation agencies and railroad companies have developed and now specify guidelines and standards for the proper design and construction of highway/railway at-grade crossings that incorporate asphalt underlayments. Contractual arrangements and design practices used by ten representative public transportation agencies and railroad companies are described herein.

At present, there is not an established quantitative measure for gauging the performance of highway/railway at-grade crossings. A simple, direct measure of the relative rideability of crossings reflective of the crossings' smoothness/roughness and its adverse effect on vehicular driver/passenger comfort and safety is desired.

The findings and conclusions contained in this report are largely qualitative. The evaluations consider the longevity of acceptable performances for many types of crossings containing many different types of crossing surfaces. The scope spans many areas of the country and analyzes crossings on both heavy rail tonnage/high highway traffic freight lines and lower tonnage/high highway traffic commuter/transit lines. Although the conclusions appear somewhat repetitious for the ten agencies, the absence of available and proven quantitative evaluation measures makes it necessary to monitor a large and widely variable sample of crossings to accurately assess the performance of asphalt underlayment over long periods of time.

Adding a layer of asphalt when constructing a new trackbed or renewing an existing trackbed will conceivably increase the cost of the crossing project compared to using an all-granular trackbed. However, for crossings that routinely exhibit short service lives due to unfavorable site conditions and poor performance, the additional cost for asphalt underlayment is minimal relative to the total cost of renewal. Typically, these crossings require the removal and replacement of the existing support and track materials with a premium surface applied. Often times, the added cost for the asphalt layer is less than 5 percent of the total renewal cost. If the crossing protection equipment is also replaced, the added percentage increase in cost will be even less. Though in most cases the cost of asphalt underlayment is minimal, it is important to note that the benefit-cost ratio varies from project to project. For crossings requiring frequent renewals, the added cost for the layer of asphalt will be more economically justifiable. Conversely, crossings that rarely exhibit structural deficiencies and maintain long service lives may not warrant the additional cost.

The time required to renew a crossing with a layer of asphalt varies considerably. This will largely depend on the project size and scope, as well as the pre-project planning and

administration. There have been cases where two-lane highways have been completely re-opened to rail traffic within four hours and highway traffic within 8 to 12 hours. In other cases, crossing renewals that have involved additional appurtenant activities have required several days. The specifics of the train traffic and highway traffic at a given crossing will undoubtedly affect the planned crossing outage.

Long-term performances of hundreds of crossings incorporating asphalt underlayment indicate overwhelming justification for its use. No crossing deterioration as a function of trackbed pumping, settlement or premature deterioration of the crossing surface- indicative of inadequate trackbed support- has been detected for a wide variety of operating conditions. The only failure mechanism exhibited for a limited number of crossings is deterioration of the crossing material which can be readily replaced with minimum expense and interruption to highway and railway traffic.

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